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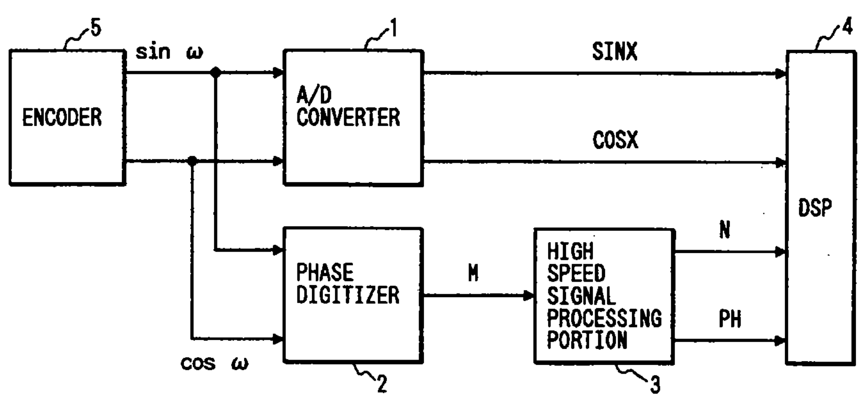
# (54) Signal processing apparatus and displacement detecting apparatus using the same.

(57) This specification discloses a signal processing apparatus for processing first and second periodic analog signals having the same period and having a fixed phase relation therebetween and having digitizing means for converting the first and second periodic analog signals into first and second digital signals in conformity with the respective amplitudes thereof, signal generating means responsive to the first and second periodic analog signals to generate a signal having a period shorter than the period of the first periodic analog signal, means for outputting the periodicity of the first periodic analog signal and first phase information of the first periodic analog signal from the signal from the signal generating means and processing means for producing second phase information of the first periodic analog signal from the first and second digital signals from the digitizing means, and correcting the periodicity from the output means on the basis of the first phase information and the second phase information.

FIG. 4

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## BACKGROUND OF THE INVENTION

### Field of the Invention

This invention relates to a signal processing apparatus for generating an interpolation signal of resolution higher than the period of a periodic signal and a position detecting apparatus using the same, and more particularly to a signal interpolation apparatus using sine and cosine wave signals generated in conformity with displacement from an encoder or the like to obtain resolution higher than the period thereof, in other words, shorter than the fundamental period, and can be well applied particularly in the field of precise position measurement and precise position control.

### Related Background Art

An example of the conventional art is shown in Figure 1 of the accompanying drawings. In Figure 1, sine and cosine wave signals generated in conformity with displacement from an encoder or the like are converted into a rectangular wave of a frequency higher than the fundamental period of the sine wave signal by the use of a phase digitizer 21 for quantizing the sine and cosine wave signals in conformity with the phase angles thereof. From this signal, a count up pulse and a count down pulse are produced by an up/down pulse output circuit 22, and these are integrated by an up/down counter circuit 23, whereby a positional signal is outputted. As the phase digitizer 21, use can be made of one having a construction as shown, for example, in Figure 2 of the accompanying drawings.

As another example of the prior art, the construction described in Japanese Laid-Open Patent Application No. 54-19773 is shown in Figure 3 of the accompanying drawings. In Figure 3, sine and cosine signals are first introduced as digital values into a microprocessor 34 by an A/D converter 31, the ratio between the values is found and the inverse tangent value thereof is calculated, and an interpolation process for finding the phase angle of the sine wave is carried out. Also, in parallel with this process, the sine and cosine signals are compared with 0V by a comparator 32 and are thereby converted into a rectangular wave, whereafter as in Figure 1, a count up pulse and a count down pulse are produced by an up/down pulse output circuit 33, and these are integrated by an up/down counter circuit 35, and the fundamental wave frequency of the sine wave signal is counted. These are synthesized by a microprocessor 34 to thereby obtain positional information.

In the conventional art shown in Figure 1, when particularly the interpolation number is great and highly accurate position detection is to be effected, the circuit scale of the phase digitizer becomes great in proportion to the interpolation number. For example, in the construction of Figure 2, the same number of comparators as the interpolation number becomes necessary and particularly, it is not realistic to digitize to 1/100 or smaller. Even if this problem is solved at all, the maximum response frequency of the up/down counter in the post stage of the phase digitizer is limited and therefore, it becomes impossible to highly accurately find the position of an object which is moving at a high speed.

The example of the prior art shown in Figure 3 intends to solve the above-noted problem to a certain degree, and an interpolation portion and a fundamental wave frequency counting portion are separated from each other to thereby provide parallel constructions, whereby even if the interpolation number is great, the circuit construction can be made small and moreover, the position of an object moving at a high speed can be detected highly accurately.

In the construction of Figure 3, however, the A/D converting portion and the phase digitizing portion operate in parallel and therefore, their operations must be executed completely in synchronism with each other, and even when only slight shift in time has occurred, there has been the possibility that mismatch occurs to positioned information obtained from each portion. In such case, there is the possibility that positional information momentarily having a great error is outputted and for example, in a case where a servo system is constructed by the use of the detected positional information, momentarily great disturbance is applied to the servo system, and this has resulted in the possibility that a fatal problem such as the collision of a moving object arises. Further, when the sine wave signal has noise, a similar problem arises and it has been impossible to obviate this.

Also, it is ideal that the sine and cosine wave signals obtained from the encoder or the like have equal amplitudes, but the amplitudes often fluctuate depending on position. Particularly when highly accurate detection is necessary, such amplitude fluctuation makes accurate interpolation calculation impossible, for example, in a portion for finding inverse tangent and therefore, in the aforedescribed cited example, there is proposed a method of correcting this in a software-like fashion by the microprocessor 34. However, particularly, amplitude correction generally involves multiplying and dividing processes and therefore, the load of the microprocessor applied thereto is great, and for example, when the same processor is used for the control calculation of the servo system, this becomes an overhead and it becomes impossible to

secure the control period short. It is possible to prepare a table or the like and curtail the amount of multiplication and division, but in such case, the greater is the interpolation number, the larger becomes the capacity of the table, and it becomes impossible to effectively utilize a memory.

## SUMMARY OF THE INVENTION

In view of the above-noted disadvantage peculiar to the conventional art, it is an object of the present invention to provide a highly reliable signal processing apparatus, a position detecting apparatus and a driving device which can make a circuit construction small even if the interpolation number is great, and which can detect a periodic signal highly accurately and can further prevent the occurrence of an error resulting from the influences of the mismatch, noise, etc. of information.

It is a further object of the present invention to provide an apparatus which can easily correct any amplitude fluctuation without increasing the load of a processor or the like.

It is still a further object of the present invention to provide an apparatus which can confirm that the operation of a phase digitizer is normal.

One form of the signal processing apparatus of the present invention for achieving the above objects is a signal processing apparatus for processing first and second periodic analog signals having the same period and having a fixed phase relation therebetween, characterized by digitizing means for converting the first and second periodic analog signals into first and second digital signals in conformity with the respective amplitudes thereof, signal generating means responsive to the first and second periodic analog signals to generate a signal having a period shorter than the period of the first periodic analog signal, means for outputting the periodicity of the first periodic analog signal and first phase information of the first periodic analog signal from the signal from the signal generating means and processing means for producing second phase information of the first periodic analog signal from the first and second digital signals from the digitizing means, and correcting the periodicity from the output means on the basis of the first phase information and the second phase information.

A preferred form of the resolution of the first phase information is characterized in that it is lower than that of the second phase information.

A preferred form of said processing means is characterized by means for comparing the first phase information and said second phase information with each other.

A preferred form of said processing means is characterized by means for synthesizing said corrected periodicity and said second phase information.

Further, a preferred form of said signal processing apparatus is characterized by means for adjusting the amplitudes of said first and second periodic analog signals on the basis of said first and second digital signals.

One form of the displacement detecting apparatus of the present invention is an apparatus for detecting the displacement of an object by the use of first and second periodic analog signals generated by the displacement of the object, having the same period and having a fixed phase relation therebetween, characterized by:

digitizing means for converting said first and second periodic analog signals into first and second digital signals in conformity with the respective amplitudes thereof, signal generating means responsive to said first and second periodic analog signals to generate a signal having a period shorter than the period of said first periodic analog signal, means for outputting the periodicity of the first periodic analog signal and first phase information of first periodic analog signal from the signal from the signal generating means and processing means having means for producing second phase information of the first periodic analog signal from the first and second digital signals from the digitizing means, and correcting the periodicity from said output means on the basis of the first phase information and the second phase information, and means for synthesizing said corrected periodicity and the second phase information and outputting the displacement information of an object.

A preferred form of the resolution of the first phase information is characterized in that it is lower than that of the second phase information.

A preferred form of said processing means is characterized by means for comparing said first phase information and the second phase information with each other.

Further, a preferred form of the displacement detecting apparatus is characterized by means for adjusting the amplitudes of the first and second periodic analog signals on the basis of said first and second digital signals.

A preferred form of the processing means is characterized by means for detecting the monotonicity of the first phase information sequentially inputted.

The signal processing apparatus of the present invention and a displacement detecting apparatus using the same will hereinafter be described in detail with respect to some embodiments thereof.

## BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is an illustration of an example of the prior art.

Figure 2 is an illustration of an example of the prior art.

Figure 3 is an illustration of an example of the prior art.

Figure 4 shows a first embodiment of the present invention.

Figure 5 is a chart illustrating the first embodiment of the present invention.

Figure 6 is a diagram illustrating a second embodiment of the present invention.

Figure 7 is a diagram illustrating a third embodiment of the present invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

A first embodiment of the present invention is shown in Figure 4. In Figure 4, the reference numeral 1 designates an A/D converter with high resolution for converting an analog signal obtained from an encoder 5 and receiving as an input an analog signal varying in a sine and cosine wave fashion for the displacement of an object into a digital signal. The A/D converter 1 is of resolution of 12 bits and attaches importance to accuracy and resolution, and operates at a relatively low speed and does not respond to an input signal of a high frequency. The reference numeral 2 denotes a phase digitizer which, like the A/D converter 1, receives as inputs sine and cosine wave analog signals obtained from the encoder 5, but attaches importance to a high speed and is of low resolution. The phase digitizer 2 is of resolution of 3 bits, and the period of the output signal thereof is shorter than the period of the signal inputted thereto. The reference numeral 3 designates a high speed signal processing portion which has the output of the phase digitizer 2 as an input and outputs the periodicity of the sine wave signal, i.e., the number of the fundamental waves of the sine wave, and a logical signal which becomes 1 within a range of 0° to 180° of the phase of the sine wave and becomes 0 within a range of 180° to 360°. The reference numeral 4 denotes a signal processing portion for receiving the outputs of the A/D converter 1 and the high speed signal processing portion 3 and effecting the signal processing of producing final positional information. A digital signal processor (DSP) is used as the signal processing portion 4 to realize high speed processing. Also, an incremental type encoder is used as the encoder 5 which outputs sine and cosine waves in conformity with position.

The procedure of these operations will hereinafter be described in succession.

The sine and cosine wave signals outputted from the encoder 5 are first inputted to the A/D converter 1 and are outputted as digital values SINX and COSX of 12 bits each. At the same time, these sine and cosine wave signals are inputted to the phase digitizer 2, which thus outputs digital data M of 3 bits which become 0 when the phase angle of the sine wave signal is 0 and which increases by 1 during each 1/8 of the period of the sine wave signal. That is, 360° of one period is divided into eight areas, and phase data digitized in the order of 0, 1, 2 counter-clockwisely from the first quadrant are allotted thereto. The high speed signal processing portion 3 receives this output M, and integrates +1 when M varies from 7 to 0, and integrates -1 when M varies from 0 to 7, and outputs the periodicity N of the obtained sine wave signal. At the same time, it outputs a logical signal PH which becomes 1 when M is within a range of 0 to 3, and becomes 0 when M is within a range of 4 to 7.

Such a construction in which the portion for counting the periodicity of the fundamental wave is endowed with redundancy to thereby obviate wrong counting caused by pulse noise or the like is a feature of the present invention.

In the DSP 4, by the use of SINX, COSX, N and PH obtained by the above-described procedure, positional information is produced by a procedure shown in the flow chart of Figure 5. That, the phase angle $\phi$ of the sine wave signal is first calculated from SINX and COSX. This can be obtained by calculating the ratio between the two values, and referring to an inverse tangent table prepared in advance by the use of the obtained value. Next, if $\phi$ exists in a range of 180° to 360° and moreover the logical signal PH from the high speed signal processing portion 3 is 0, that is, indicates that it is 180° to 360°, it is judged that mismatch has occurred between the data obtained from the A/D converter 1 and the data obtained by way of the phase digitizer 2. That is, the judgment standard is always considered to be the A/D converter 1 side and it can be judged that the value N which ought to increase by 1 in the high speed signal processing portion 3 is not yet actually incremented and accordingly, in order to eliminate this mismatch, the correcting process of increasing N by 1 to thereby provide N' = N + 1 is carried out within the DSP 4. If conversely to this case, $\phi$ exists in a range of 180° to 360° and moreover the logical signal PH from the high speed signal processing portion 3 is 1, that is, indicates that it is from 0° to 180°, it is judged that 1 more has been integrated in the high speed signal processing portion, and N is subtracted by 1 to thereby provide

N' = N - 1. When these two conditions do not apply, there is no mismatch between the data obtained from the A/D converter 1 and the data obtained by way of the phase digitizer 2 and therefore, the correction as described above is not necessary and N' = N is provided. Thereafter, the obtained N' and the phase angle $\phi$ can be added to thereby obtain final positional information.

By providing the correcting means as described above, there can be constructed a highly accurate position detecting apparatus in which the mismatch between the data obtained from the signal processing portions provided in parallel can be prevented to thereby eliminate any momentary detection error and which is stable and moreover can cope with high speed motion.

A second embodiment of the present invention is shown in Figure 6. This embodiment is one which a multiplication type D/A converter 6 for correcting the amplitudes of the signals from the encoder 5 is added to the first embodiment shown in Figure 4.

This embodiment is similar in the basic processing procedure to the first embodiment, but in this embodiment, by the utilization of the fact that the digital data obtained from the A/D converter 1 are always introduced into the DSP 4, the maximum values and minimum values of the A/D converted data SINX and COSX of the sine and cosine wave signals are held within the DSP 4. Further, each time the signals from the encoder 5 are A/D-converted, these maximum values and minimum values are successively renewed to thereby hold optimum maximum and minimum values at all times. The amplitudes of the sine wave and cosine wave signals are then calculated and a correction signal is outputted to the multiplication type D/A converter 6 so that they become equal to each other, whereby the data are set and the correction of the amplitudes of the signals from the encoder 5 is effected.

By providing such gain correcting means, any error included in the phase angle data $\phi$ due to the unbalance of the gain can be eliminated to thereby enhance the linearity thereof particularly when the calculation for finding the inverse tangent shown in the flow chart of Figure 5 is effected. The signals from the encoder 5 can also be set to as great as possible amplitudes in the A/D converter 1 and phase digitizer 2 in conformity with their maximum input voltages and therefore, the influence of a quantization error occurring when the signals from the encoder 5 become small can be minimized. When the input voltage widths of the A/D converter 1 and phase digitizer 2 differ from each other, multiplication type D/A converters can be prepared discretely or the signals can be suitably attenuated after they have passed through the D/A converter 6.

Further, a digital filter is prepared within the DSP 4 and high frequency noise which may be included in the signals from the encoder 5 is attenuated to a sufficiently negligible level by filter calculation. Since the digital filter processing by software is possible, there can be provided a filter having a desired cut-off/phase characteristic, such as an FIR filter of linear phase.

In the above-described embodiment, a phase digitizer of at least 1 bit is used with the portion for counting the periodicity of the fundamental wave to give redundancy, thereby improving resistance to disturbance. Also, provision is made of a variable gain amplifier positively utilizing the phase information obtained in the phase digitizer portion to effect correction or error detection when the information obtained on the interpolation side and the periodicity of the fundermental wave are synthesized, and further correcting the amplitudes of the sine and cosine wave signals.

As a third embodiment of the present invention, there is shown the construction of Figure 7 in which an electromagnetic motor 7 and a motor driver 8 are added as an actuator to the construction of Figure 6 to thereby provide a positioning servo system. The angle of the motor is highly accurately detected by the procedure shown in the above-described embodiment to thereby construct such a control system that this coincides with a desired target position. Control calculation constituting an appropriate compensator on the basis of the detected angle data is effected within the DSP 4 and a current reference value to the motor obtained as a result is given to the motor driver 8, whereby the highly accurate positioning of the motor becomes possible.

At this time, the redundancy realized by the phase digitizer 2 is utilized more positively. That is, a logical signal ERR which becomes U as long as the phase-digitized value M increases by 1 each or decreases by 1 each and which becomes 1 when M varies to 2 or greater at a time, that is, when the monotonicity of M becomes null is generated by the high speed signal processing portion and is introduced into the DSP 4. When the logical signal ERR has become 1, it is judged that some sudden disturbance has been inputted from a mechanical system, and for example, the output current of the driver 8 is rendered 0 to thereby once stop the servo operation, thus informing the operator that abnormality has happened. Thereby, a problem that the servo system is destroyed by an abnormal operation due to a great detection error, disturbance or the like can be obviated, and a highly reliable servo system can be constructed.

The invention may be embodied in other specific forms without departing from the spirit or

essential characteristics thereof. The above-described embodiments are thereby to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

This specification discloses a signal processing apparatus for processing first and second periodic analog signals having the same period and having a fixed phase relation therebetween and having digitizing means for converting the first and second periodic analog signals into first and second digital signals in conformity with the respective amplitudes thereof, signal generating means responsive to the first and second periodic analog signals to generate a signal having a period shorter than the period of the first periodic analog signal, means for outputting the periodicity of the first periodic analog signal and first phase information of the first periodic analog signal from the signal from the signal generating means and processing means for producing second phase information of the first periodic analog signal from the first and second digital signals from the digitizing means, and correcting the periodicity from the output means on the basis of the first phase information and the second phase information.

## Claims

1. A signal processing apparatus for processing first and second periodic analog signals having the same period and having a fixed phase relation therebetween, comprising:

   digitising means for converting said first and second periodic analog signals into first and second digital signals in conformity with the respective amplitudes thereof;

   signal generating means responsive to said first and second periodic analog signals to generate a signal having a period shorter than the period of said first periodic analog signal;

   means for outputting the periodicity of said first periodic analog signal and first phase information of said first periodic analog signal from the signal from said signal generating means; and

   processing means for producing second phase information of said first periodic analog signal from said first and second digital signals from said digitizing means, and correcting the periodicity from said output means on the basis of said first phase information and said second phase information.

2. The apparatus of Claim 1, wherein the resolution of said first phase information is lower than that of said second phase information.

3. The apparatus of Claim 1, wherein said processing means has means for comparing said first phase information and said second phase information with each other.

4. The apparatus of Claim 1, wherein said processing means has means for synthesizing said corrected periodicity and said second phase information.

5. The apparatus of Claim 1, further comprising means for adjusting the amplitudes of said first and second periodic analog signals on the basis of said first and second digital signals.

6. An apparatus for detecting the displacement of an object by the use of first and second periodic analog signals generated by the displacement of the object, having the same period and having a fixed phase relation therebetween, having:

   digitizing means for converting said first and second periodic analog signals into first and second digital signals in conformity with the respective amplitudes thereof;

   signal generating means responsive to said first and second periodic analog signals to generate a signal having a period shorter than the period of said first periodic analog signal;

   means for outputting the periodicity of said first periodic analog signal and first phase information of said first periodic analog signal from the signal from said signal generating means; and

   processing means having means for producing second phase information of said first periodic analog signal from said first and second digital signals from said digitizing means, and correcting the periodicity from said output means on the basis of said first phase information and said second phase information, and means for synthesizing said corrected periodicity and said second phase information and outputting the displacement information of the object.

7. The apparatus of Claim 6, wherein the resolution of said first phase information is lower than that of said second phase information.

8. The apparatus of Claim 6, wherein said processing means has means for comparing said first phase information and said second phase information with each other.

9. The apparatus of Claim 6, further comprising means for adjusting the amplitudes of said first and second periodic analog signals on the basis of said first and second digital signals.

10. The apparatus of Claim 6, wherein said processing means has means for detecting the monotonicity of said first phase information sequentially inputted.

FIG. 1

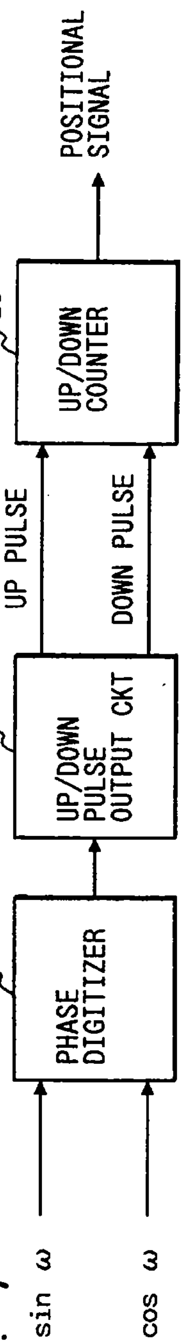
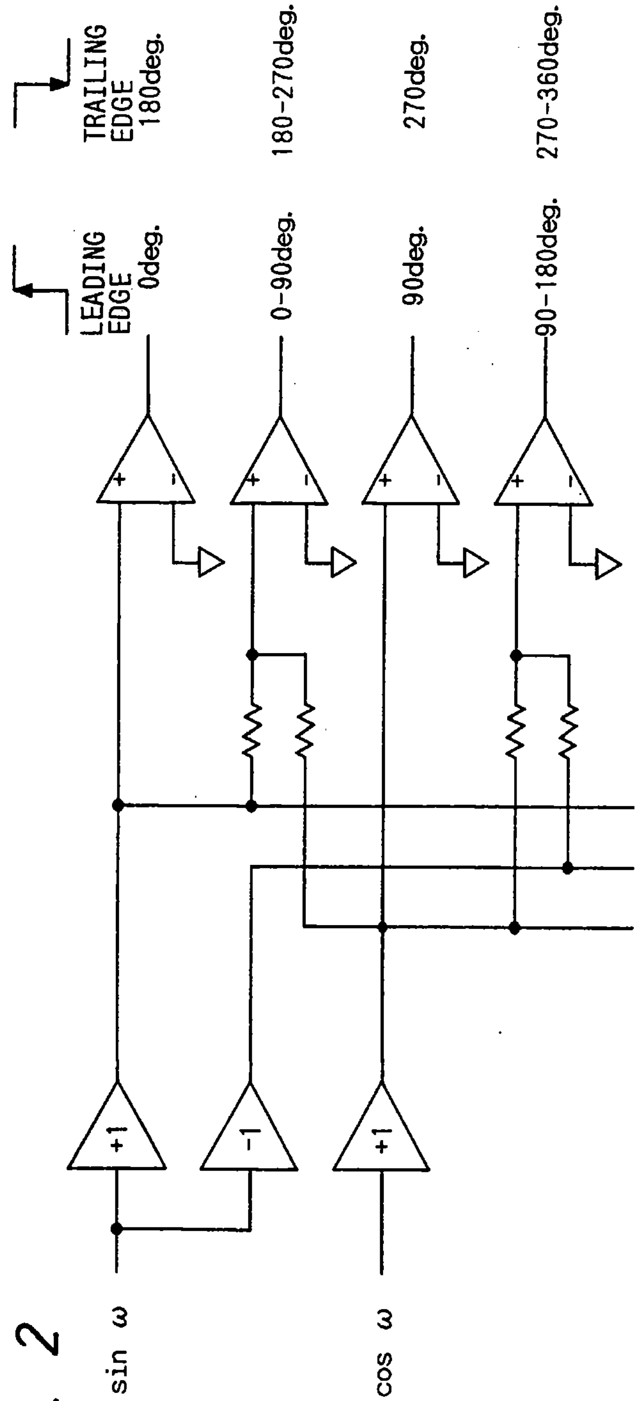
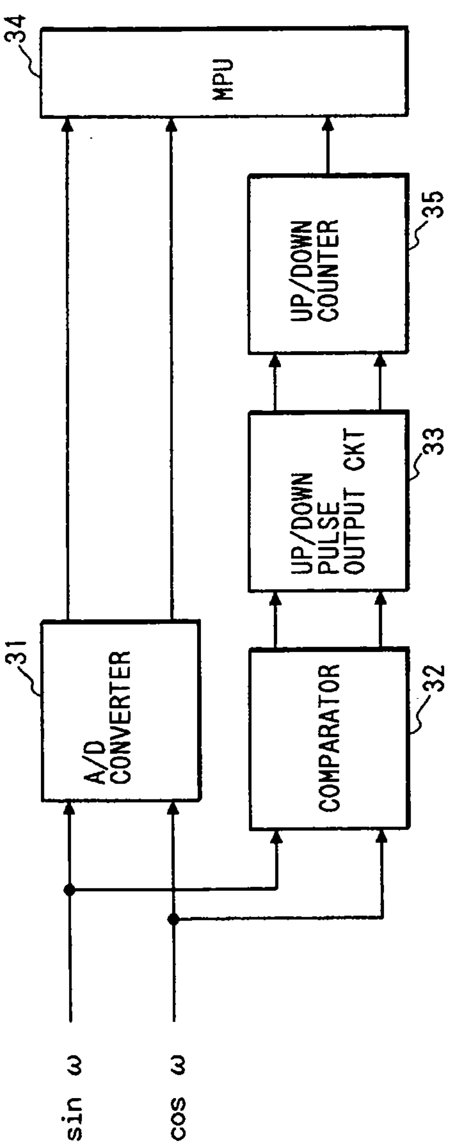

sin ω
cos ω
21
PHASE DIGITIZER
22
UP/DOWN PULSE OUTPUT CKT
UP PULSE
DOWN PULSE
23
UP/DOWN COUNTER
POSITIONAL SIGNAL

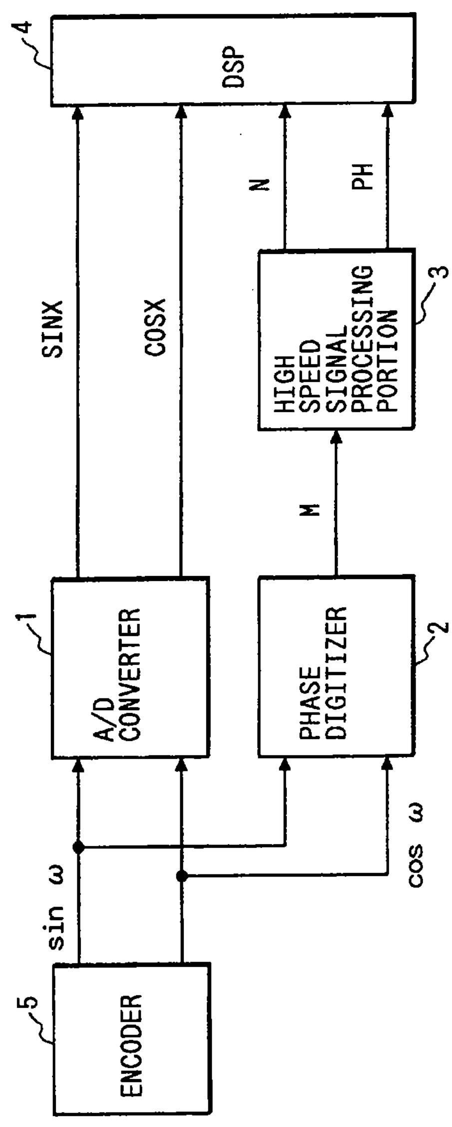
FIG. 2


sin ω
cos ω
+1
-1
+1
LEADING EDGE 0deg.
TRAILING EDGE 180deg.
0-90deg.
180-270deg.
90deg.
270deg.
90-180deg.
270-360deg.



34
MPU
31
A/D CONVERTER
sin ω
cos ω
32
COMPARATOR
33
UP/DOWN PULSE OUTPUT CKT
35
UP/DOWN COUNTER

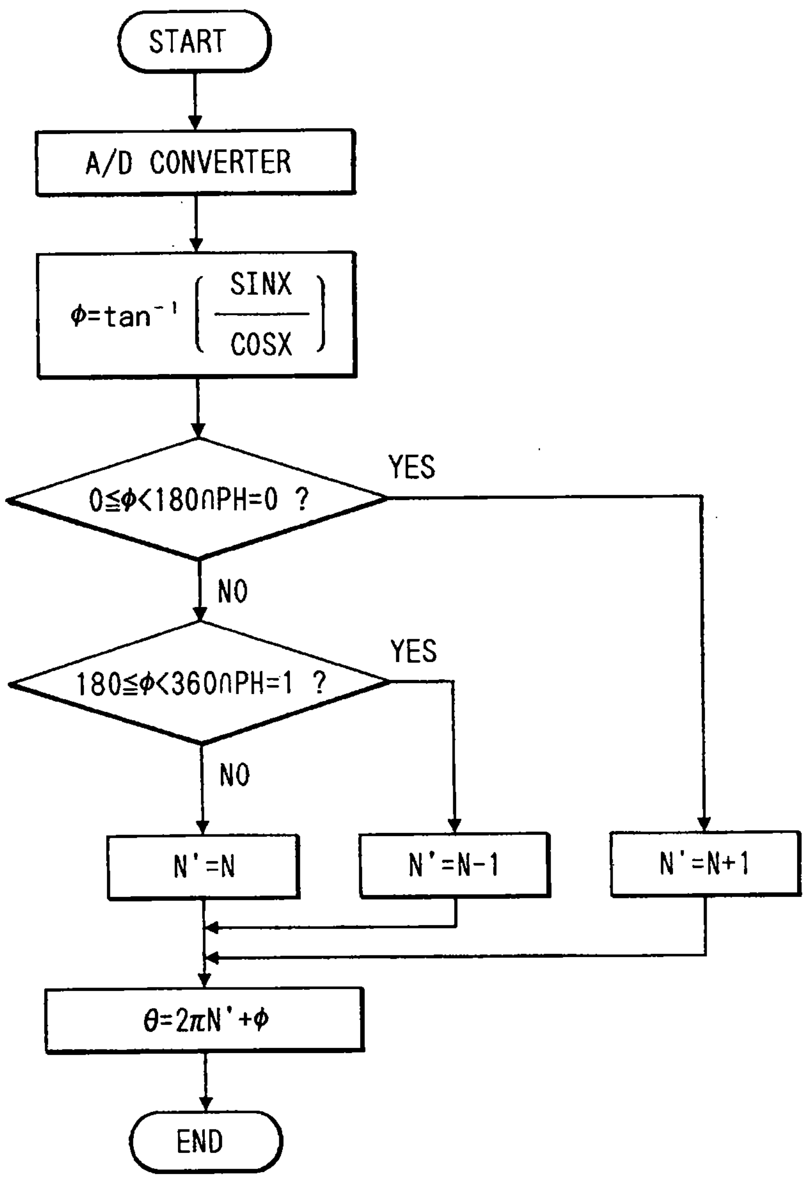

FIG. 3



4
DSP
5
ENCODER
sin ω
cos ω
1
A/D CONVERTER
SINX
COSX
2
PHASE DIGITIZER
M
3
HIGH SPEED SIGNAL PROCESSING PORTION
N
PH


FIG. 4

FIG. 5


START
A/D CONVERTER
φ=tan⁻¹(SINX/COSX)
0≦φ<180∩PH=0 ?
YES
NO
180≦φ<360∩PH=1 ?
YES
NO
N'=N
N'=N-1
N'=N+1
θ=2πN'+φ
END

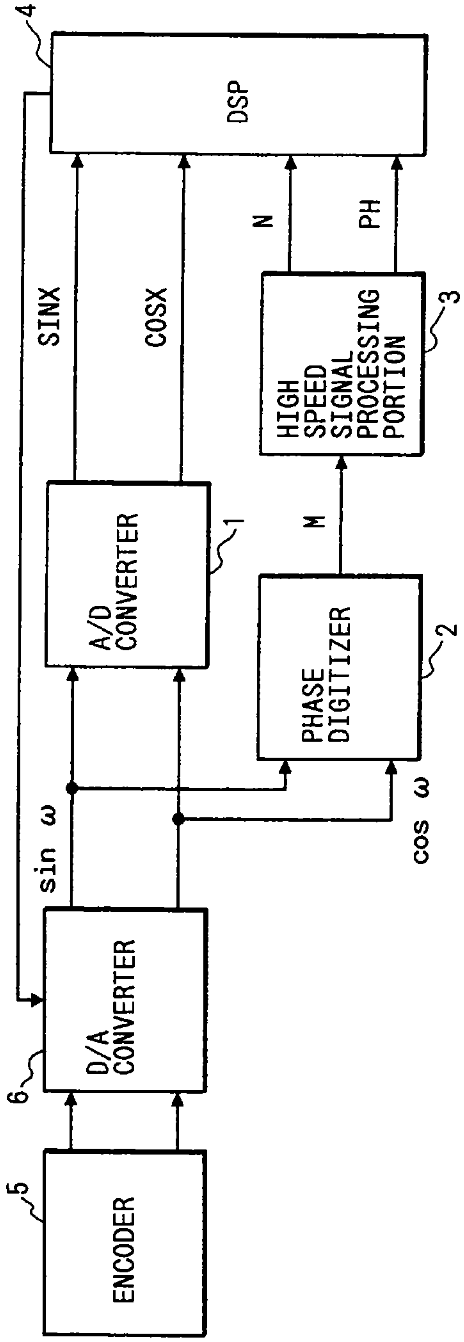

DSP
4
SINX
COSX
N
PH
HIGH SPEED SIGNAL PROCESSING PORTION
3
A/D CONVERTER
1
M
PHASE DIGITIZER
2
sin ω
cos ω
D/A CONVERTER
6
ENCODER
5

FIG. 6

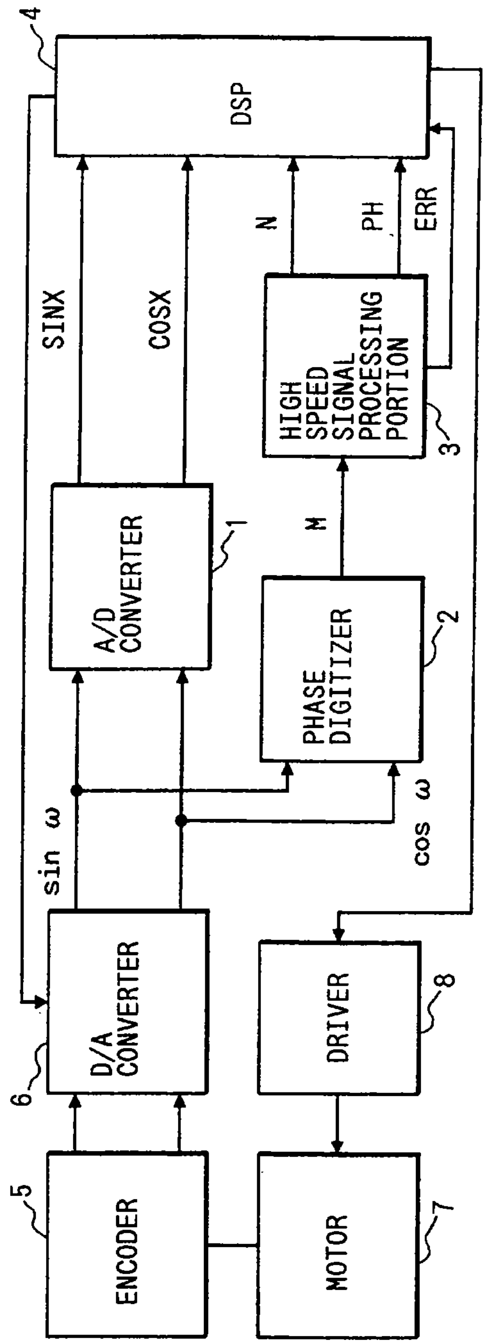

DSP
4
SINX
COSX
N
PH
ERR
HIGH SPEED SIGNAL PROCESSING PORTION
3
A/D CONVERTER
1
M
PHASE DIGITIZER
2
sin ω
cos ω
D/A CONVERTER
6
DRIVER
8
ENCODER
5
MOTOR
7

FIG. 7